A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

LA-UR -83-2590

CONF-8308106--16

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

LA-UR--83-2590

DE84 001351

TITLE: FIELD STUDIES OF EROSION-CONTROL TECHNOLOGIES FOR ARID SHALLOW LAND-BURIAL SITES AT LOS ALAMOS

AUTHOR(S) J.W. Nyhan
W.V. Abeele
G.L. DePoorter
T.E. Hakonson
B.A. Perkins
G.R. Foster

SUBMITTED TO Fifth Annual DOE LLWP Participants Information Meeting, August 30, 1983 Denver, CO

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FIELD STUDIES OF EROSION CONTROL TECHNOLOGIES FOR ARID SHALLOW LAND BURIAL SITES AT LOS ALAMOS

J.W. Nyhan, W.V. Abeele, G.L. DePoorter,
T.E. Hakonson, B.A. Perkins, G.R. Foster*
Los Alamos National Laboratory

ABSTRACT

The field research program involving corrective measures technologies for arid shallow land-burial sites is described. Reasearch performed for a portion of this task, the identification, evaluation, and modeling of erosion control technologies, is presented in detail. In a joint study with USDA-ARS, soil erosion and infiltration of water into a simulated trench cap with various surface treatments was measured and compared with data from undisturbed soil surfaces with natural plant cover. The distribution of soil particles in the runoff was measured for inclusion in CREAMS (a field scale model for Chemicals, Runoff and Erosion from Agricultural Management Systems). Neutron moisture gauge data collected beneath the erosion plots are presented to show the seasonal effects of the erosion control technologies on the subsurface component of the water balance.

INTRODUCTION

Once the burial trench receives its final cover, several environmental processes start influencing the configuration and integrity of the surface and subsurface of the trench cap (Fig. 1). The most serious problems encountered in shallow land burial are related to water management,[1] as water comes into contact with the buried wastes either from infiltration of precipitation, or from trench cap erosion leading to the exposure of the buried waste. Unfortunately, management practices that reduce erosion of the trench cap may enhance infiltration; thus, burial site operators must ultimately arrive at techniques which will balance control of infiltration and erosion.

The overall purpose of the corrective measures task is to develop and test methods that can be used to correct any actual or anticipated problems with new and existing SLB sites in an arid environment. These field tests will not only evaluate remedial actions, but will also investigate phenomena suspected of being a possible problem at arid SLB sites. The approach we have taken in developing remedial action technology for low-level waste sites is to recognize that physical and biological processes affecting site integity are interdependent, and, therefore, cannot be treated as separate problems.

Specifically the research performed for this task will field test second generation biointrusion barriers, determine by field experiments the extent of upward radionuclide migration due to moisture cycling, measure the effects of subsidence on remedial action or other system components, and identify, evaluate, and model erosion control technologies. The CREAMS model, (A Field Scale model for Chemicals, Runoff, and Erosion From Agricultural Management Systems) will be used to model the surface processes[2] and will be validated for soil profiles typical of that in SLB facilities.

---

*Environmental Science Group, Los Alamos National Laboratory and G.R. Foster, U.S. Department of Agriculture, Agricultural Research Service.

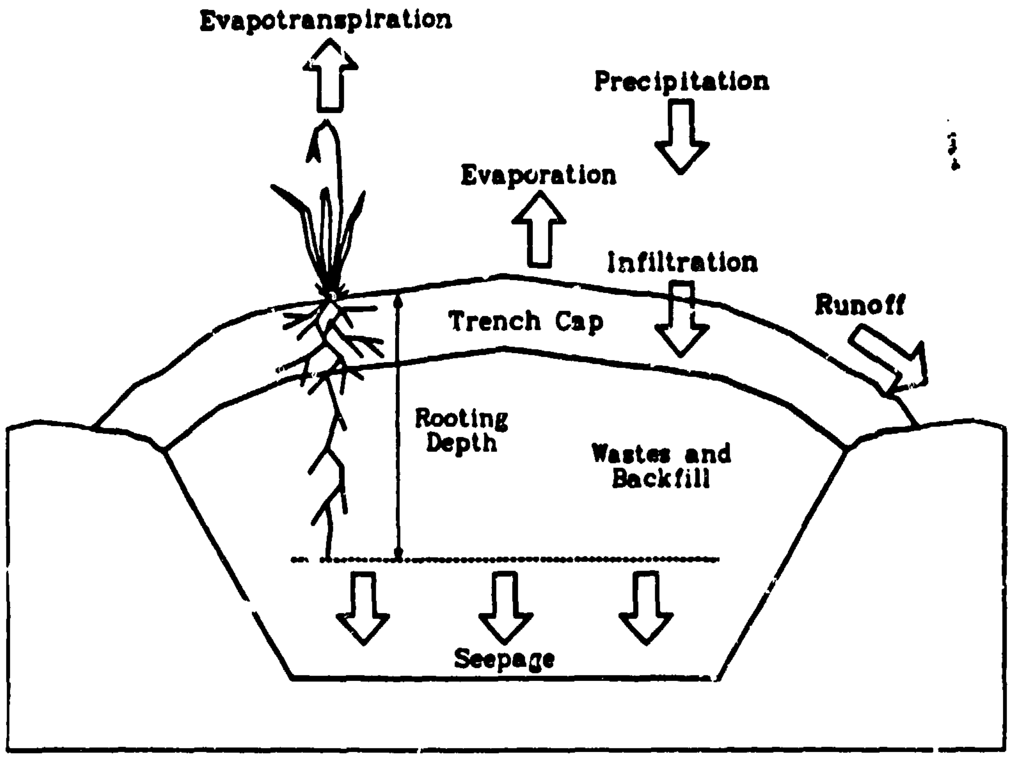

Fig. 1. Hydrology of the shallow land-burial trench.

Several accomplishments were made in the first three subtasks. The second generation biointrusion barrier subtask involved installing a cobble-gravel biobarrier at Area B at Los Alamos (a burial site closed out initially in 1947) and emplacing a smaller scale, more controlled biobarrier system in the experimental clusters; water balance relationships and the ability of the plants to take up a label beneath the barrier were then monitored with time. The moisture cycling experiment was finally harvested, resulting in an emphasis on sampling, data analysis, and interpretation. A large scale subsidence experiment was emplaced and is currently being monitored for subsidence and soil water changes with time.

The results of the erosion control technology subtask will be presented in detail in the following sections of this paper.

EROSION CONTROL TECHNOLOGY SUBTASK: DESCRIPTION OF SITE AND METHODS

The objective of this subtask was to investigate the water balance and erosional behavior of burial trench caps of several cover conditions. Plots were established at the Los Alamos Experimental Engineered Test Facility (EETF) on conditions very closely matching trench caps used for shallow land burial at Los Alamos[3]. These plots were exposed to simulated rainfall to generate infiltration, runoff and erosion during the simulated rainfall events. The effect of antecedent soil water content on these hydrologic variables was also evaluated, and the soil erodibility factor and the cover management factor of the Universal Soil Loss Equation (USLE) were estimated for our trench cap configuration. Data from the study will be used in modeling the hydrologic performance and design of trench caps for specific conditions.[4]

A 15.2 × 62.5 m simulated trench cap was constructed at the EETF in Los Alamos, New Mexico.[5] The configuration of this trench cap consisted of a 15-cm layer of backfilled Hackroy series topsoil,[6] which has been stockpiled at the site, underlain by a 90-cm layer of crushed Bandelier tuff backfill, classified as belonging to geologic Mapping Unit 3.[7] Both layers were installed with dominant downhill slopes of 7%. We compared the hydrologic behavior of this highly disturbed system with an adjacent undisturbed soil profile with natural cover.

Three treatments were imposed on the 8 plots on the trench cap in standard 3.1 × 11 m plots with the long axis parallel to the slope.[8,9] Two plots received an up and down slope disking (cultivated treatment); these were comparable except for lengthened slope to the USLE unit plot of continuous tilled fallow used to determine the USLE erodibility and cover management factors. Two others were not tilled and also received no vegetative cover (bare soil treatment). In order to determine the influence of vegetation on soil erosion, four plots were seeded with barley (*Hordeum vulgare L.*).

The rainfall simulator used was a trailer-mounted rotating-boom simulator capable of applying 60 mm/h,[10] with drop size distributions similar to those of natural rainfall,[11] and rainfall energies about 80% of those of natural rainfall. The rain simulator run sequence consisted of an initial 60 minute rainfall simulation at existing levels of soil water (dry soil surface), a 30 minute run 24 hours later (wet soil surface), and another 30 minute run after a 30 minute delay (very wet soil surface).[9] The simulated rainfall rate was always about 60 mm/h, and these simulated rain events were applied to the plots in late June, 1982, when the barley was one month old, thus minimizing canopy effects on soil erosion.

Soil loss for each simulated rainstorm was calculated as the product of runoff rate and the concentration of sediments in the runoff. The flumes used to measure runoff have a capacity of about 4 L s^{-1} with water level recorders modified according to Simanton and Renard.[9] The sediment concentration in each runoff sample, was determined by weighing the sample, allowing about 40 days for the sediment particles to settle to the bottom of the sample jars, decanting the water, and weighing the sample jar and dried sediment after a three-day drying period at 60°C. Sediment samples were then wet sieved into various fractions down to 53 microns, and the less than 53 micron fraction assayed for particle sizes down to 1.9 microns in diameter with a Leeds and Northrup Microtrac particle size analyzer.

Rainfall amount and application rate were measured using a recording raingauge that was placed between each plot pair. The distribution of rainfall over each erosion plot was measured with 4 gauges that recorded rainfall amount near each of the plot corners.

Long term soil water changes were monitored with a neutron moisture gauge in three 1.7 m-long access tubes positioned in each erosion plot.

RESULTS AND DISCUSSION

In this section we will present typical hydrograph and sedigraph data obtained during the rain simulator runs, show how the total soil loss data and the soil erodibility and cover management factors are derived from these data, and present information on the distribution of sediment particles in the runoff from each plot treatment. Short- and long-term changes in subsurface soil water content will then be discussed.

Soil Loss Data

Hydrograph, sediment concentration, and sedigraph data are presented in Fig. 2 for typical rain simulator runs on the trench cap receiving cultivated, bare soil, and barley cover treatments and for an erosion plot with natural plant cover.

During the period of gradually increasing runoff in the dry surface runs on the plot with natural plant cover, sediment concentrations remained relatively constant (0.35 to 0.41%), so that sediment loss rates gradually increased to a maximum of 64.9 g/min (Fig. 2). In the successive wet and very wet soil surface simulator runs, runoff occurred more promptly after the start of the rain event than previous runoff events on the plot, reflecting the decreased infiltration rate into increasingly wet soil profiles. Peak sediment concentrations, ranging from 0.40 to 0.54%, and peak sediment loss rates, ranging from 97 to 109 g/min, were not found until the final very wet surface simulator run, clearly showing the effect of antecedent moisture on these hydrologic parameters. During the simulator run on the dry soil surface on the cultivated plot (Fig. 2), discharge rates quickly increased to 40 - 46 mm/h and sediment concentrations ranging from 8.4 to 10.8% were observed. This resulted in maximum sediment loss rates of 2677 g/min for this rain simulator event (Fig. 2), which exhibited sediment concentrations and loss rates on this plot that were 20-25 times larger than on the

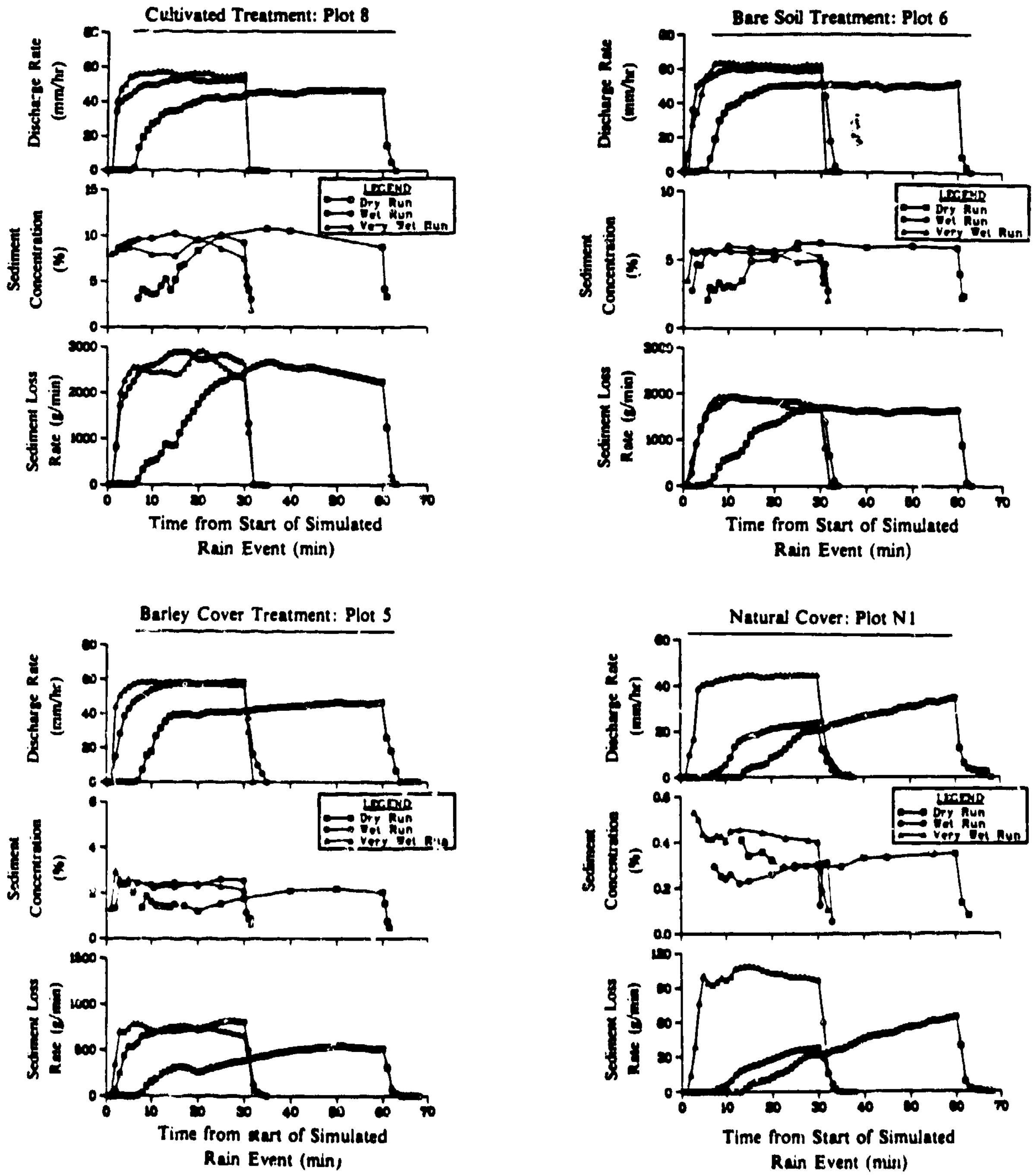

Fig. 2. Hydrology, sediment concentration, and sedigraph data for erosion plots with cultivated bare soil, barley cover, and natural cover treatments.

natural cover plots. Changes in sediment concentrations during all three simulated rain events influenced the sedigraph data more than the relatively uniform discharge rate curves (Fig. 2). This suggests that sediment transport-deposition processes and interactions during the events were dynamic, which, in turn, suggests the occurrence (as was observed in the bottom 3 m of the plot after the three rainstorms applied) of sediment redistribution processes near and in the furrows formed on the plot.

Although discharge rates for the bare soil, barley cover, and cultivated treatments were similar, sediment concentrations varied considerably between treatments (Fig. 2). Maximum sediment concentrations from the smooth bare soil plot were only 6.0%, much less than the 10.8% concentration found on the cultivated plot. Sediment concentrations from the plot with barley cover were even lower, ranging from 1.5 to 2.2% during peak runoff for the dry soil surface run, and from 2.0 to 2.6% during the wet and very wet simulator runs.

The hydrograph and sedigraph data for each rain simulator run were integrated over time, and the average runoff and soil loss amounts for each surface treatment are shown in Table 1. Average soil losses for each simulator run on the natural plots ranged from 0.7 to 3.4% of the losses on the cultivated plots, whereas the bare soil and barley cover treatments exhibited 64 to 67% and 29 to 38% of the losses from the cultivated plots. The influence of antecedent soil water content on water erosion can also definitely be shown for all of the trench cap plots. Thus soil loss rates increased from 19-53% between the dry and very wet soil surface simulator runs, and only increased 1-7% between the wet and very wet soil surface runs (Table 1). We used the soil loss data to estimate values for the soil erodibility (K) and cover management (C) factors of the USLE. Values for K were calculated from the measured soil losses from the cultivated plots and the energy and intensity of the simulated rainstorms applied to these plots. Soil losses from the three rain simulator runs on the cultivated plots were summed and adjusted for soil loss from the standard unit plot (22.1-m length, 9% slope) according to Agricultural Handbook 537.[8] The average K factor for all three simulator runs on both tilled plots was then calculated by dividing the unit-plot adjusted soil loss by the estimated energy-times-intensity factor of the rain events, resulting in a K values of 0.085 t·ha·h/ha·MJ·mm with a coefficient of variation [(standard deviation of mean/mean)(100)] of 16% (n=6). This K value agrees quite well with the estimate of 0.079 t·ha·h/ha·MJ·mm, which we derived from the soil erodibility nomograph.[8,12]

The cover management factor (C) in the USLE is the ratio of the soil loss at a specific crop stage to the corresponding loss from the clean-tilled, unprotected soil of a unit plot. Thus, we calculated the soil loss ratios for the barley cover and natural cover treatments by dividing the total soil loss from all three simulator runs, adjusted for soil loss from the standard unit plot,[8] by the corresponding soil loss from the tilled plots (Table 2). Soil loss ratios ranged from 0.267 to 0.426 for the barley plots and from 0.013 to 0.023 for the plots with natural vegetative cover. These soil loss ratios agreed quite well with estimates from other research performed throughout the United States.[8]

Transport of Soil Particles by Overland Flow from Erosion Plots

A knowledge of the various-sized soil particles transported in runoff is needed to accurately predict

TABLE 1

AVERAGE RUNOFF AND SOIL LOSS FOR RAIN SIMULATOR RUNS ON DRY, WET, AND VERY WET SOIL SURFACE ON EROSION PLOTS AS A FUNCTION OF SURFACE TREATMENT

Treatment (Number of Plots)	Average Runoff (mm)			Average Soil Loss (kg)		
	Dry Surface[a]	Wet Surface[a]	Very Wet Surface[a]	Dry Surface	Wet Surface	Very Wet Surface
Natural Cover (2)	14.5	6.0	18.7	1.47	0.46	2.24
Cultivated (2)	44.1	25.0	27.2	104.93	65.37	66.09
Bare Coil (2)	46.7	26.8	28.4	70.55	41.88	44.58
Barley Cover (4)	37.9	26.5	27.6	30.56	23.43	24.84

[a]Represents an initial 60 min rainfall simulation (dry surface), a 30 min run 24 hours later (wet surface), and another 30 min run after a 30 min delay (very wet surface), all performed at a rainfall rate of 60 mm/hour.

TABLE 2

ESTIMATES OF COVER MANAGEMENT FACTORS (C) FOR THE TRENCH CAP PLOTS WITH BARLEY COVER AND THE NATURAL PLOTS

Plot Number	Total Soil Loss (t/ha[a])	C Factors[b]
Trench Cap Plots with Barley Cover		
2	45	0.43
4	28	0.27
5	28	0.27
7	39	0.37
Natural Plots		
N1	2.4	0.023
N2	1.3	0.013

[a]Sum of soil losses from plot during dry, wet, and very wet soil surface rain simulator runs, adjusted for losses from a standard USLE unit plot.

[b]Total soil loss from the vegetated plot/average total soil loss from the cultivated erosion plots.

erosion of trench cap covers using US Department of Agriculture models such as CREAMS.[2-4] Thus about 60 of our runoff samples were assayed for particle size distributions as a function of sampling time, soil surface treatment, and antedecent soil water conditions. Log-probability plots of these data were made, where the log of the sediment diameter is plotted as a function of the cumulative percentage of the particles, expressed on a probability scale (Fig. 3). The average particle diameter was determined from plots like these, and typical data are summarized in Table 3.

We performed a detailed analysis of variance of all the data, which showed that plot surface treatment was not a statistically significant influence in this experiment. However, for the three surface treatments on the disturbed soil profiles on the trench cap, average sediment particle size was found to increase with time and with wetter initial soil surface conditions. The undisturbed plots with natural cover showed a different hydrologic response with time and antecedent moisture conditions. We think this comparison has exciting long-term implications for waste management programs, since the disturbed soil profiles on the trench cap will gradually evolve, over hundreds of years, to become similar to those on our natural plots.

Temporal Changes in Soil Water Content Beneath the Trench Cap

Long-term changes in soil water content beneath the trench cap need to be monitored to evaluate percolation of rain water into the underlying wastes. The average runoff-precipitation ratios determined in our study are presented in Table 4 for what happened during all of the simulated rains, followed by a set of typical neutron moisture gauge data to show subsurface changes in soil water content with time (Fig. 4).

Only 14 mm of runoff occurred during the dry soil surface run from the plots with natural vegetative cover, resulting in a runoff-precipitation ratio of 0.26 (Table 4), while soil loss was 1.47 kg (Table 1). In contrast, the runoff-precipitation ratios for all of the trench cap plots ranged from 0.75 to 0.99, indicating that only 1.0 to 25% of the water infiltrated this configuration during the simulated rain.

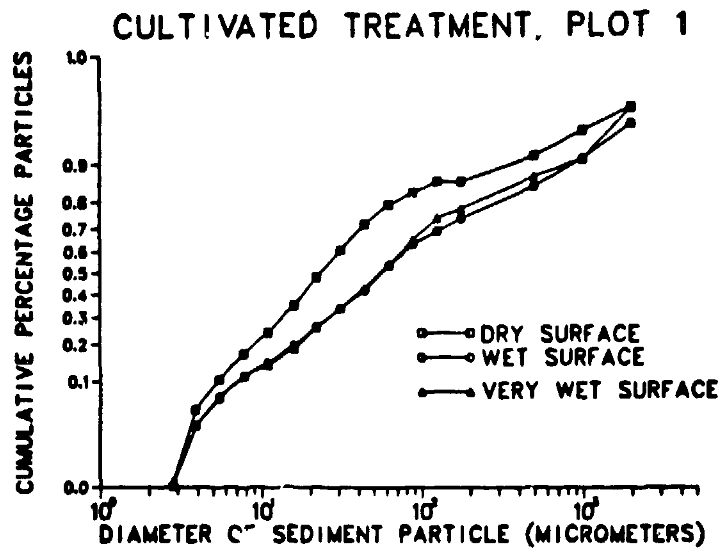

Fig. 3. Particle size distribution data for runoff samples collected from an erosion plot with a cultivated surface treatment.

TABLE 3

AVERAGE PARTICLE DIAMETER ESTIMATES FOR RUNOFF SAMPLES AS A FUNCTION OF PLOT TREATMENT AND SAMPLING DURING DRY, WET, AND VERY WET SOIL SURFACE RAIN SIMULATOR RUNS

Plot Treatment	Time (min)[a]	Average Particle Diameter (microns) Dry Soil Run	Wet Soil Run	Very Wet Soil Run
Tilled	1	23	57	57
	2	48	60	72
Bare	1	22	70	65
Soil	2	50	75	180
Barley	1	18	50	50
Cover	2	50	55	65
Natural	1	126	300	62
Cover	2	61	235	45

[a]Times 1 and 2 represent samples collected a few minutes after runoff started and at the peak discharge rate just before the end of the simulated rain.

TABLE 4

AVERAGE RUNOFF/PRECIPITATION RATIOS FOR RAIN SIMULATOR RUNS ON DRY, WET, AND VERY WET SOIL SURFACES ON EROSION PLOTS AS A FUNCTION OF SURFACE TREATMENT

Treatment (Number of Plots)	Average Runoff/Precipitation Dry[a] Surface	Wet[a] Surface	Very Wet[a] Surface
Natural Cover (2)	0.26	0.28	0.65
Cultivated (2)	0.82	0.93	0.94
Bare Soil (2)	0.90	0.92	0.99
Barley Cover (4)	0.75	0.92	0.95

[a]Represents an initial 60 min rainfall simulation (dry surface), a 30 min run 24 hours later (wet surface), and another 30 min run after a 30 min delay (very wet surface), all performed at a rainfall rate of 6 mm/hour.

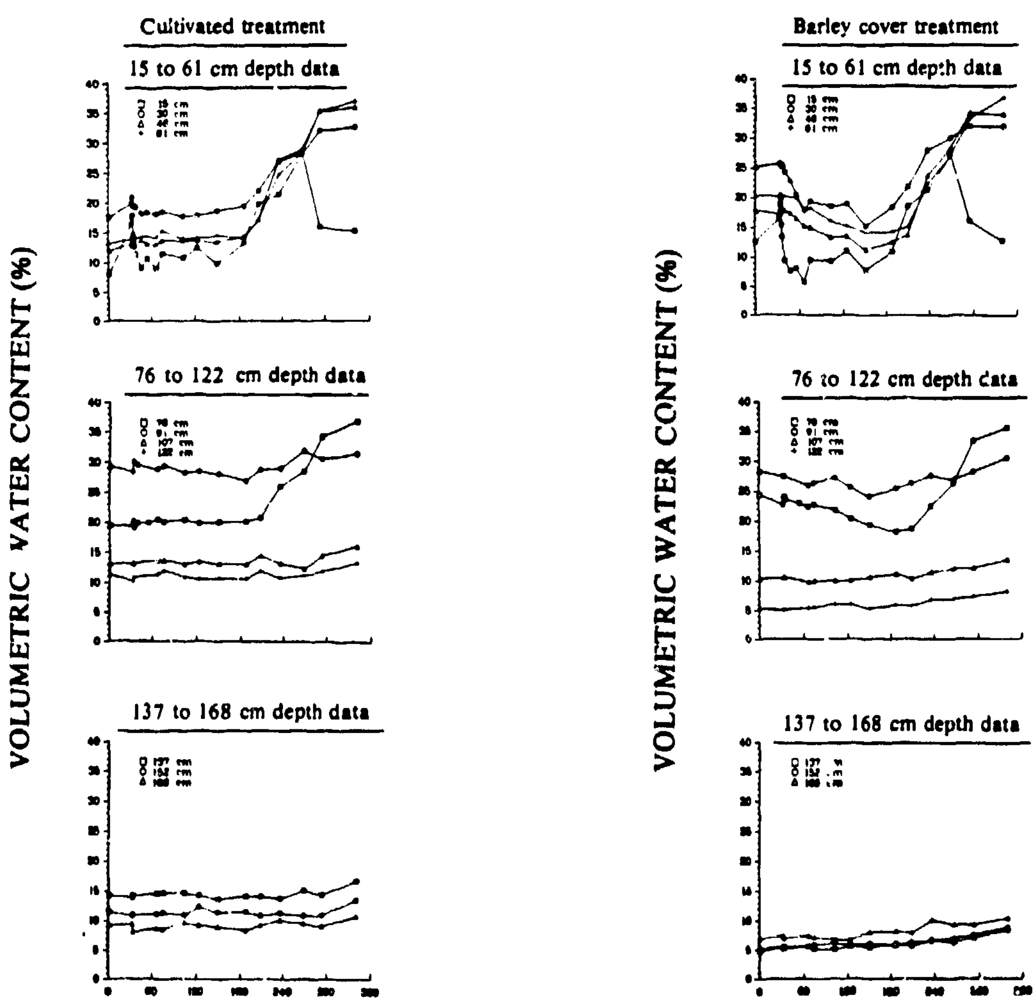

Fig. 4. Neutron moisture gauge data collected from 15 to 168 cm beneath two erosion plots with the cultivated and barley cover treatments (day 1 to day 340 represents data collected from May 21, 1982 through April 25, 1983).

Typical neutron moisture gauge data are presented for several sampling depths for a cultivated erosion plot and an erosion plot with barley cover (Fig. 4). These data confirm the information presented in Table 4 that very little infiltration of water occurred during the simulator runs. Thus, in spite of the fact that approximately 110 mm of water was applied to each of these plots on June 22 and 23 (33 and 34 days on the figures), no increase in soil water was detected at any depth over that observed before the simulated rainfall on June 21. Interestingly enough, large increases in soil moisture were found up to 90 cm below the surface of the trench cap as a result of melting snow after the December 14 readings (208 days data in Fig. 4). During time periods when the barley was actively transpiring, we also noticed decreases in soil water content close to the surface of the trench cap, which were not observed in the disked plot with no vegetation (Fig. 4).

These seasonal trends in subsurface water levels have important waste management implications (Fig. 1) since the fine-textured trench cap used in this field experiment (Fig. 3) is similar to the clay caps commonly installed as a remedial action cure over a pre-existing burial trench with hydrologic problems. The neutron moisture gauge data are currently being analyzed in greater detail to derive estimates of evaporation, evapotranspiration, and percolation of water in the trench cap. These data will also be used to validate CREAMS and models used to predict unsaturated water flow rates for multilayered trench caps with various surface treatments.

REFERENCES

1. Jacobs, D. G., J. S. Epler, and R. R. Rose, "Identification of Technical Problems Encountered in the Shallow Land Burial of Low-Level Radioactive Wastes," Oak Ridge National Laboratory report ORNL/SUB-80/13619/1, Oak Ridge, Tennessee, 1980.

2. Knisel, W. G., Jr., Ed., "CREAMS: A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems," US Department of Agriculture Conservation Research report No. 26, May 1980.

3. Warren, J. L., "Shallow Land Burial: Experience and Developments at Los Alamos," in "Underground Disposal of Radioactive Wastes," International Atomic Energy Agency, Vienna, 1980, pp.221-240.

4. Nyhan, J. W. and L. J. Lane, "Use of a State of the Art Model in Generic Designs of Shallow Land Repositories for Low-Level Wastes," R. G. Post and M. E. Wacks, Eds., in "Waste Management '82," University of Arizona, Tucson, 1982.

5. DePoorter, G. E., "The Los Alamos Experimental Engineered Waste Burial Facility: Design Considerations and Preliminary Experimental Plan," R. G. Post and M. E. Wacks, Eds., in "Waste Management '81," Proc. of the Symposium on Waste Management, University of Arizona, Tucson, 1981.

6. Nyhan, J. W., L. W. Hacker, T. E. Calhoun, and D. L. Young, "Soil Survey of Los Alamos County, New Mexico," Los Alamos Scientific Laboratory report LA-6779-MS, 1978.

7. Rogers, M. A., "History and Environmental Setting of LASL Near-Surface Land Disposal Facilities for Radioactive Wastes (Areas A, B, C, D, E, F, G, and T)," Los Alamos Scientific Laboratory report LA-6848-MS, Vol. 1, 1977.

8. Wischmeier, W. H. and D. D. Smith, "Predicting Rainfall Erosion Losses—A Guide to Conservation Planning," US Department of Agriculture, Handbook No. 537, US Government Printing Office, Washington, DC, 1978.

9. Simanton, J. R. and K. G. R. Renard, "Seasonal Change in Infiltration and Erosion from USLE Plots in Southeastern Arizona," Hydrology and Water Resources in Arizona and the Southwest 12: 37-46, Arizona Academy of Science, Tempe, 1982.

10. Swanson, N. P., "Rotating-Boom Rainfall Simulator, Trans. Amer. Soc. Agric. Eng 8: 71-72, 1965.

11. Swanson, N. P., "Field Plot Rainfall Simulation (Rotating-Boom Rainfall Simulator), Lincoln, Nebraska Proc. Rainfall Simulator Workshop, 166-169, US Department of Agriculture, Tucson, 1979.

12. Wischmeier, W. H., C. B. Johnson, and B. V. Cross, "A Soil Erodibility Nomograph for Farmland and Construction Sites," J. Soil and Water Conserv. 26:189-192, 1971.